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WATER CONSERVATION TO MINIMIZE THE EFFECT OF DROUGHT

AGRICULTURAL RESEARCH SERVICE
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Water Conservation to Minimize the Effect of Drought

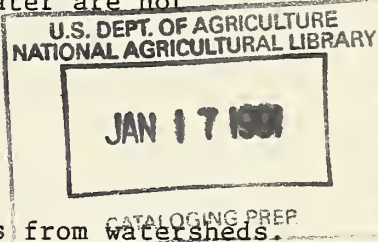
Water is the primary factor which limits crop yields during every growing season in the vast arid and semiarid regions of the U.S. Crop yields are often limited in the humid regions by water shortages during critical periods of the growing season even though the total annual rainfall is almost always more than the total amount of water required for crop production. Even irrigated areas are affected by droughts in the upland regions where water for irrigation is collected.

Research on water conservation and ways to augment deficient water supplies has been a major effort of the Agricultural Research Service for many years. Several articles are listed below which present an overview of the practices available to minimize the effects of drought. More specific articles are grouped in the following categories:

1. Conservation practices and tillage to improve water storage in the soil.
2. Control of water losses by evaporation and seepage.
3. Use of drought resistant crops and reduction of plant populations.
4. Increasing water use efficiency in irrigated systems.
5. Water harvesting.
6. Matching fertilizer applications to available soil moisture.
7. Limited irrigation when optimum quantities of water are not available.
8. Use of saline or brackish water for irrigation.
9. Use of waste water.
10. Effect of agricultural practices on water yields from watersheds.
11. Snow management for water conservation.
12. Mulches and minimum tillage.
13. Wind erosion control.
14. Range management and conservation of water supplies for livestock.
15. Irrigation at critical stages of plant growth.

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Conservation Practices and Tillage to Improve Water Storage

A deficiency of water is the major factor which limits plant growth on rangelands and non-irrigated cultivated croplands in the semiarid northern Great Plains.

So far man has not, by design, been able to influence the quantity and distribution of incident precipitation to appreciably improve land productivity. Management practices have been developed to conserve and increase the use-efficiency of available water supplies.

To illustrate both the importance of an additional inch of available water and the varying degrees of efficiency with which water is used in different places, the regression equations of wheat yield on available water for the eastern Washington and the Northern Plains States are cited. In eastern Washington an extra inch of stored soil moisture plus rainfall added 5.8 bushels of wheat per acre. The intercept of water with zero yield was 4.1 inches, indicating at least statistically that this amount of water was required just to produce the vegetative plant. For the Northern Plains, 8 inches of water are needed just to produce the plant, and 2.9 bushels per acre are added for each additional inch of stored soil water plus rainfall. The precipitation in eastern Washington occurs in the winter and early spring when evaporation is low, whereas the precipitation in the Northern Plains occurs largely in the spring and early summer period of wheat growth when evaporation is high. Of course, varietal differences are also involved. The fact that an appreciable amount of water is used just to grow a failure means that each additional inch of water has a marked effect in increasing the overall water-use efficiency for grain production. Data derived from 17 dryland experiment stations in the Great Plains, showed that, on the average, an additional inch of stored soil moisture increase spring wheat yields 2.44 bushels and winter wheat yields 2.74 bushels an acre.

Insufficient stored soil water at planting often limits corn production. For example, a minimum of 5 in of available soil water at planting time was needed to produce 64 bushels per acre of corn (Holt, et al., 1964) and about 10 bushels of corn per acre is obtained from each in of stored water at planting. Depletion of soil water to the wilting percentage for 6 to 8 days during the tasseling period reduced corn yields 50%. Increasing stored soil water is, therefore, a means to increase crop production throughout much of the major agricultural production area of the United States.

The greatest opportunity to replenish soil water exists during the dormant season or cold months. During this time, evaporative potential is low, plant activity is passive, and the soil is relatively dry and therefore, receptive to infiltration. The primary obstacle to soil water recharge during this period is soil frost and the soil's inherent incapacity to infiltrate water as rapidly as the rate of snowmelt or rainfall.

occurs. Redistribution of snow by wind also renders some of the water supply unavailable for soil recharge over areas blown free of snow. Following are some range treatments designed to augment natural recharge of soil water for subsequent seasonal use by detention storage of precipitation and by facilitating favorable distribution of snowfall.

Contour Furrowing:

This land surface treatment is commonly accomplished by disk or lister-type implements to construct contour furrows from about 1 foot to 3 feet wide, 3 to 8 inches deep, and spaced about 4 to 6 feet apart so as to store an equivalent surface water depth of 1 to 2 inches. Intra-furrow dams are normally constructed and spaced about 15-30 feet apart to prevent breaching of furrows that do not strictly adhere to the contour.

Contour furrowing affects soil water recharge by (1) rainfall and snow-melt runoff retention, (2) improved infiltration, and (3) holding incident snowfall in place against wind removal. The treatment has been most effective on those sites where runoff is moderate to high. Central Nebraska's contour furrows reduced runoff by 84 to 95 percent and in southeastern Montana, runoff from a furrowed, fine-textured range site averaged 1 inch annually compared to 3.6 inches from natural watersheds. Data from these same watersheds showed that snowpack water equivalent on furrowed and nonfurrowed watersheds averaged 2.2 and 1.4 inches, respectively; overwinter soil water recharge, 2.5 and 0.9 inches; available early spring water, 3.6 and 1.6 inches; and herbage yield, 645 and 260 lb/A. Overwinter recharge accounted for 50% of the increased herbage production resulting from contour furrowing.

Pitting:

Pitting has been done with a variety of implements for the purpose of creating relatively shallow soil indentations of about 1 foot wide to 2-3 feet long, spaced a few feet apart in a grid pattern across the landscape. Typical surface storage is 1/3 to 1/2 inch of water. By improving the soil water regime, species composition, and initially at least the rate of soil nitrification, forage production has been increased in the northern Great Plains by about 30 to 50%. In north-central Montana; pitting, by reducing clubmoss cover 25 to 70%, increased ground cover of perennial grasses and sedges. In southeastern Wyoming, pitting increased sheep-carrying capacity by 32% and lamb gains 10 lb/A/year. Because pitting disturbs the soil surface relatively little as compared to furrowing, relatively less soil water is stored and longevity is shorter.

Level Bench Terracing:

The most severe, expensive, and potentially effective land surface modification treatment is level bench terracing. These terraces are long, flat, level in all directions, and diked at the ends and downslope side to store considerable water. Studies in North Dakota showed that overwinter water storage averaged 1.42 inches on nontreated slopes and

ranged from 4.8 to 9.1 inches on level benches over a 5-year period. This increase was attributed mainly to the increased deposition of snow behind the dikes on the level benches and the detention of snowmelt until such time as the soil thawed and the water could infiltrate. The increased stored soil water increased grass and alfalfa production. Alfalfa averaged 3,000 lb/A/year on untreated slopes and ranged from 6,400 to 8,500 lb/A/year on level benches. In another study, bromegrass production increased from 890 lb/A on untreated slopes to 1,650 lb/A on level benches; with nitrogen fertilizer, respective yields were 1,890 and 3,140 lb/A.

Other Land Treatments:

Ripping and chiseling; scalping, a scaled-down version of contour furrowing used primarily for seeding in native prairie; gully plugging; and water-spreading systems, which are built to fit the terrain to concentrate water from steeper areas for spreading over gentler down-slope areas, are other techniques employed to manage water. As with any practice, the above treatments, when applied to help solve a specific problem or achieve specific objectives, all have merit.

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Control Water Losses by Evaporation and Seepage

Considerable amounts of water can be lost from the delivery systems of irrigation systems. For example, an average of 41 percent of the irrigation water was lost from the delivery system of a project in Nevada from 1914-1955 before the water reached the farm. Seepage losses in canals and reservoirs can be controlled to a degree by lining with various materials such as asphalt, butyl rubber, chemical treatment, concrete, earth and plastic. Losses due to both seepage and evaporation during water distribution could be almost completely eliminated by using pipe distribution systems. This may become economically feasible due to the increased value of water and development of new materials for pipes.

Small water-impounding structures offer the only feasible source of water on many farms and ranches. The average evaporation in the 17 Western States ranges from 24 to 84 inches and is several times the annual precipitation in many areas.

Various types of floating reflective covers are effective in reducing evaporation from small stock tanks. In addition to the various linings mentioned above, seepage from stock tanks in calcium-aggregated soils can be greatly reduced by treatment with sodium carbonate without soil compaction. Water borne-asphalt emulsions are useful in reducing seepage from leaky reservoirs that cannot be dewatered.

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Use of Drought Resistant Crops and Reduction of Plant Populations

We depend on about 15 plant species for most of the food consumed directly by man. Other species provide forage for animals. None of these 15 primary species can survive in the desert without irrigation. Long-season corn, sugarcane, sugar beets, cassava, rice, yams, sweet potatoes, long-season bean varieties, and peanuts are poorly adapted to semiarid conditions because of their high water requirement. Wheat, short-season corn varieties, barley, oats, grain sorghum, peas, millets, and potatoes are more successful because they have shorter growing seasons and lower total water needs. Millets can be grown where water is inadequate for grain sorghum, and grain sorghum can be grown in areas where corn will not produce.

In areas which depend on water stored in the soil during the fall and winter for much of the crop water requirement, a crop with a relatively low water requirement may provide a yield even though the amount of stored moisture at planting time is well below average. Selection of a crop with a deep root system or one which can endure a period of water stress and still produce after summer rains occur should be considered also. Of course, the availability of a market for various crops cannot be ignored.

Another possibility is to plant seed more thinly so that the evaporation from plant and soil is less than that from a thickly planted crop. The use of 40 pounds of winter wheat seed is common on dry land, whereas 120 pounds would be used on irrigated areas. The thin stand uses the available water more slowly than the thick stand so that growth is not interrupted by a drought. The thick stand will use the available water immediately and "burn up" before the fruiting stage is reached. Weed control is important because weeds compete with the crops for soil water and may have an advantage in thinly planted croplands.

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Increasing Water Use Efficiency in Irrigated Systems

The amount of irrigation water required includes the water used by the crop (consumptive use) plus water needed to leach soluble salts below the root zone (leaching requirement). The actual water applied includes these amounts plus the water lost by deep percolation and runoff.

To provide a suitable moisture environment in the soil for plant growth, the water must be uniformly distributed over the soil surface. The amount applied should not exceed the available water storage capacity of the soil profile in the root zone plus any leaching requirement. This requires careful scheduling of irrigations for each field using meteorological, soil and crop data, along with field inspection. A USDA-ARS irrigation scheduling computer program using meteorological techniques and soil-crop data has been developed and used in several western states. An irrigation management service is often needed to supplement practical irrigation experience with the scientific irrigation techniques on a day-to-day basis. The potential economic return to the farmer can exceed the cost of this service severalfold.

Preventing runoff is almost impossible in some areas where the uptake rate of the soil is fairly low and the land slope does not permit leveling. The use of on-farm water recirculating systems may be used to conserve water where irrigation water is obtained from deep wells. Recycling irrigation tail water into the main canal systems is used in irrigation districts with an extensive network of canals.

Recent research indicates that it may be possible to reduce the leaching fraction required to maintain plant growth by developing moisture conditions in the soil which result in salt precipitation. This technique requires accurate metering of the water applied and high uniformity of water distribution. The infiltration rate must be controlled by applying water at a rate that does not exceed the hydraulic conductivity so that it will infiltrate at the application rate. Trickle irrigation systems or carefully operated pivot or solid set sprinkler systems approach this condition. The technology required to engineer such a system, based on uniform, high frequency, and low rate application of water exists today but it has not been field tested.

On a short term basis, the amount of water used for leaching may be reduced or eliminated during a year when the supply of irrigation water is limited if enough water to prevent long term salt accumulation is applied in succeeding years when more irrigation water is available.

Water use efficiency may be increased by applying water to maximize crop production per unit of water applied rather than to maximize yields per acre. In Arizona, cotton yields were about equal when water was applied at 5 percent more and 10 percent less than consumptive use whereas yields decreased 18 percent when 30 percent less than consumptive use was applied. Cabbage yields were the same when water was

applied at 30 percent and 5 percent more than consumptive use, but yields were decreased 10 percent and 43 percent, respectively, when 20 percent and 50 percent less than the consumptive use requirement was applied. Also, short season cotton production requires one less irrigation than conventionally managed fields. Yields are reduced but production costs may be lower due to more efficient water use and lower insecticide applications.

In some cases, water can be conserved by using trickle irrigation systems rather than furrow irrigation. The consumptive use requirements of row crops probably are about the same for all methods of irrigation, but trickle irrigation systems have a high application efficiency on almost all soils. Furrow irrigation may be quite efficient on a heavy or medium textured soil but not on very sandy soils. Trickle irrigation probably is more efficient than furrow irrigation for orchards.

Sprinkler irrigation can also be used to improve irrigation efficiency on sandy soils. Almost all soils that have intake rates higher than 0.5 inch per hour are irrigated by sprinklers. Moving systems increase application uniformity, and downward directed sprays near the crop level reduce wind drift losses.

Another efficient irrigation system is called "dead level irrigation." This method consists of smoothing the land as nearly level as possible and building low dikes around the fields. Large streams of water are turned into these areas for short periods of time until the desired quantity of water has been applied. No water runs off and the large stream covers the field rapidly, giving good distribution. Only the desired amount is applied. Labor requirements are relatively low and the system can be automated. This method is well adapted to areas having homogenous or low intake soils, light rainfall, salt problems, and relatively flat terrain.

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Water Harvesting

Water harvesting--the collection and storage of precipitation runoff from areas treated to reduce intake--is a method of microclimate modification that has been practiced for several thousand years. Although essentially abandoned with the development of central water systems, this method is receiving renewed attention (as demand on existing supplies increases) and promises tremendous potential for increasing available water supplies in many areas.

As an example of its potential, only about 3 percent of the precipitation that falls each year on the State of Arizona is collected, stored, and beneficially used. Much of the other 97 percent is lost or non-beneficially used, but could be collected. Harvested water sometimes costs less than other means of supply. Of equal or greater importance, installation of water harvesting systems permits use of previously unusable rangeland, because drinking water supplies were inadequate. Water harvesting can also supply water for wildlife.

For example, in southern Utah, the installation of three water harvesting systems on a 19,000-acre allotment increased primary range from 3,500 acres (18 percent) to about 7,500 acres (38 percent), thus increasing considerably the productivity and carrying capacity of the allotment.

Intake reduction (water harvesting) has been accomplished in a number of ways, including smoothing, compacting, shaping, chemical and physical sealants, and membrane coverings. Several approaches to storage of the harvested water have also been investigated such as pits, bags, and tanks. Results demonstrate the economic importance of saving the water after it is collected.

Another modification of water harvesting is runoff farming where water from one area of land is directed to another area to increase crop growth. Also, water harvesting may have potential for collecting water for municipalities.

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Matching Fertilizer Applications To Available Soil Moisture

The amount of moisture stored in the soil profile should be used as a guide in determining the amount of nitrogen (N) fertilizer which should be applied. In dry years, excessive N fertilization can decrease grain yields by increasing the rate of water use early in the season so that the plant lacks sufficient available water to carry it through periods of stress. In Texas, a method to determine fertilizer needs was developed using the stored water content and weather data from previous years. Similar fertilizer recommendations can be developed for other dryland areas using fertilizer response data and weather records for that area in a computer simulation of crop growth and water balances.

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Limited Irrigation When Optimum Quantities of Water As Not Available

Limited irrigation is defined as management of irrigation water at a level below the requirement for maximum plant growth and yields. The success of this practice depends upon: (1) Use of crops, such as grain sorghum, cotton, and winter wheat which are drought tolerant and possess good growth recovery ability following irrigation and rainfall; (2) These crops possess critical stages of development where grain or lint yield response to irrigation is relatively high; (3) Water applied as preplant or during early vegetative development can be reduced considerably without corresponding reductions in grain and lint yields; and (4) Seasonal rainfall can usually furnish a substantial proportion of plant water needs.

Supplementing rainfall with limited irrigation is an important water management concept for efficient water use in the irrigated Southern High Plains. For example, research at Bushland, Texas, showed that if only 4 inches of irrigation water is available for a grain sorghum crop, it could be used most efficiently by applying the 4 inches of water during one irrigation at heading or milk stage of grain. Water use efficiency could also be improved by reducing the size of several seasonal irrigation from 4 inches to 2 inches even though yields were decreased. Irrigation timing was also important when less an optimum amount of water was applied to winter wheat. The most critical stage for adequate soil moisture was from booting through early grain filling. One well timed spring application increased yields more than two poorly timed applications, and two well-timed spring applications increased yields more than three poorly timed applications.

On some soils alternate furrow irrigation offers opportunity for reducing the size of the irrigation and increasing water use efficiency. Another system which efficiently uses limited water supplies is irrigated winter wheat followed by fallow and then non-irrigated sorghum in a no-till management system. Surface residue produced by irrigated winter wheat increased soil water storage during fallow resulting in higher yields than those from the conventionally tilled area.

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Use of Saline or Brackish Water for Irrigation

In arid zones, the ground water often has a high enough salt content to be harmful to plant growth. However, highly saline water can be used for irrigation if careful management practices are followed. Also, salinity problems are not entirely restricted to arid regions. Sometimes when water is needed for supplemental irrigation in coastal areas the only available irrigation source is brackish water.

The range of salinity that can be reasonably tolerated by different crops extends from about 1300 to about 13,000 ppm in the saturation extract. However, two- or three-fold concentration of salt in a soil solution occurs even with good management. In judging the suitability of irrigation water, the salt content and proportion of different ions in the water, the characteristics of the soil to be irrigated and the management practices used must be considered. The Sodium-Adsorption-Ratio (SAR) is one of the most useful measures of water quality. Usually, for waters of equal total salt content, one having a high SAR will be more hazardous than one having a low SAR value.

Highly saline waters can be used for irrigation under certain conditions. Salt tolerant crops such as grasses for seed, barley, sugar beets, bermudagrass, cotton and wheat grass may be grown if water penetration is good and adequate supplies of the saline water are available to prevent salt accumulation in the soil. Water containing 5000-10,000 ppm total salt have been used by farmers. At the U.S. Salinity Laboratory, waters containing 12,000-15,000 ppm total salt have been used to produce good yields when the most tolerant crops were planted, cultural practices were used to avoid salt accumulation around the seed and seedling and soils were used which allowed the penetration of enough saline water to minimize salt accumulation.

In humid areas, yield increases from supplemental irrigation with brackish water may be large enough to offset any decrease resulting from salinization and rainfall is high enough to prevent the long-term accumulation of salts.

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Use of Waste Water

In water deficient areas, waste waters such as sewage water, food processing plant effluents, or even some industrial plant effluents, can be an important water resource. Secondary sewage effluents can be used for irrigating crops that are processed before consumption, crops that are not used for human consumption such as forages, or for lawns and golf courses. The use of primary sewage is usually restricted to crops that are not consumed by humans. However, regulations vary for various states. Sewage water can be renovated by ponding it on sandy soils and allowing it to filter through the soil to the ground water or to a tile drain collection system. This reclaimed water can be used for unrestricted irrigation, recreational lakes, or by industry.

Waste water from plants processing vegetables or poultry is suitable for unrestricted irrigation under most conditions. However, the waste water from some processing plants is not suitable for irrigation due to high concentrations of sodium.

Other waste waters, such as industrial wastes, may or may not be suitable for irrigation, depending upon their concentrations of salts, heavy metals, or toxic chemicals.

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Effect of Agricultural Practices on Water Yield from Watersheds

The U.S. Department of Agriculture has been engaged in research on the hydrology of agricultural watersheds since 1917. A wealth of practical information is available from the Agricultural Research Service on the role of soils and vegetation in infiltration, evapotranspiration, storage and release of water, geologic control of deeper flows, and on the movement of water overland or through channels and reservoirs.

Experimental watersheds are instrumented to develop procedures for predicting the moisture balance on each of the important soils and land uses occurring in the major land resource area. Sizes of the 150 such watersheds range from 1 to 500 acres. Instrumentation may also provide for measuring streamflow of several tributaries, recording water-surface profiles for flood-routing studies, and observing ground water levels. Documentation and interpretation of the hydrologic performance of the watersheds over a range of climatic and storm conditions provide the basis for development and refinement of prediction procedures. The principles and procedures developed from this research can be used along with a knowledge of the geology, soils, topography and vegetation of an ungaged watershed to predict its performance under various land use and climatic conditions. For example, the runoff from an ungaged watershed could be predicted for various rainfall intensities.

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Snow Management for Water Conservation

In the Western United States, two snow situations exist. On mid-elevation, rangeland areas, falling snow is moved and redistributed by winds. At higher elevations and generally forested areas, snow is stored as a deep and more uniform snowpack. Each situation has unique management opportunities to insure a maximum deposition of snow water and to regulate snowmelt processes to provide optimum water supplies for downstream uses.

Conservation of rangeland snow requires the stabilization of falling and blowing snow as soon as possible to reduce water losses from wind movement, which increases the potential for sublimation. As much as 1/3 of the winter precipitation is lost by sublimation during redistribution events and by evaporation during the melt season. Deposition in drifts of optimum location, size and shape, minimizes melt season evaporation.

Vegetative barriers and experimental wood-slat fences can be used to conserve water by trapping snow and shaping snowdrifts. For example, the tall wheat-grass barrier system shows great promise for increasing snow water supplies through snow trapping, with the added bonus of controlling wind erosion.

The high country snowpack setting requires mainly an improvement in water supply forecasting. Accurate and timely forecasts of runoff from snowpack are needed to predict the availability of water for downstream water storage and use for irrigation, power generation, recreation, fisheries and transportation. It was estimated in 1969 that a 1% improvement in the water supply forecast on the Columbia River at the Dalles Dam would be worth \$6,000,000 for power and irrigation alone.

Cooperative research between ARS and SCS, in the Boise River basin, Idaho, is contributing to the development of more accurate forecasting and measurement of snowpack water yields.

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Minimum Tillage And Mulches

Surface residues and mulches have been shown to greatly influence infiltration. After several hours of water application, intake rates were up to five times greater for straw covered soil surfaces compared to bare soil surfaces. Fall mulch filled surfaces provided eight times greater infiltration capacity before runoff commenced and four times greater infiltration during runoff the following spring than did fall plowed surfaces that were disked and harrowed in the spring. Water loss for mulch tillage of corn planted on the contour in Ohio was only 5% of that for conventional tillage. Similar results were obtained in Wisconsin, however, the reduction of runoff attributable to mulch is less with noncontoured plots.

There are some limitations associated with mulch tillage. In the Northern Corn Belt, early season soil temperatures are critical to early corn growth. Mulches tend to decrease soil temperatures and early growth. Reduction of evaporation under mulches in the Great Plains may be minor due to limited rainfall and amounts of crop residue. However, total evaporation might be reduced by utilization of available residues in concentrated zones on less than the entire surface. A strip of soil can be cleaned to avoid seedling damage by depressed soil temperatures.

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Wind Erosion Control

Establishing and maintaining vegetation or vegetative covers, producing stable clods, roughening the land, reducing field lengths, and leveling or benching the land are the five principles of wind erosion control.

Residues can maintain a surface cover until the crop is established. The effectiveness of residue on wind erosion depends on texture, amount, orientation, and spatial distribution. Tillage must be performed in a way to conserve as much residue as possible. Conservation and minimum tillage do a better job of this than conventional tillage. Also, the kind and amount of tillage performed with conservation tillage reduces soil pulverization and smoothing and does a better job of providing the optimum 2- to 5-inch roughness than does conventional tillage.

Cropping systems that utilize strip cropping rotations and wind barriers reduce wind erosion. For example, any cropping system that reduces field length will also reduce the rate of wind erosion.

Windbarriers modify or decrease the wind force on the adjacent soil surface and improve crop growth and yields by modifying the microclimate next to barriers. Field research has shown several kinds of trees, shrubs and grasses which can be grown in semiarid areas without special care or maintenance. Some promising species are red cedar, Russian mulberry, tamarisk, pampas grass, American plum, Siberian elm, Russian olive, and caranga. Perennial grass barriers in northeastern Montana controlled wind erosion and trapped snow to uniform depths, resulting in increased soil water storage and subsequent crop yields.

Recent research at Manhattan, Kansas, has shown that 14 tons of surface-applied wet manure or 23 tons of tilled-in-wet manure were effective in keeping erosion below the accepted 5 ton per acre limit.

One approach toward preventing wind erosion for 5 to 7 weeks before the crop establishes a canopy to protect the soil surface is to spray the soil at seeding time with commercially available stabilizers. Asphalt emulsion and a petroleum resin-in-water emulsion appeared economically feasible in temporarily preventing wind erosion in Kansas.

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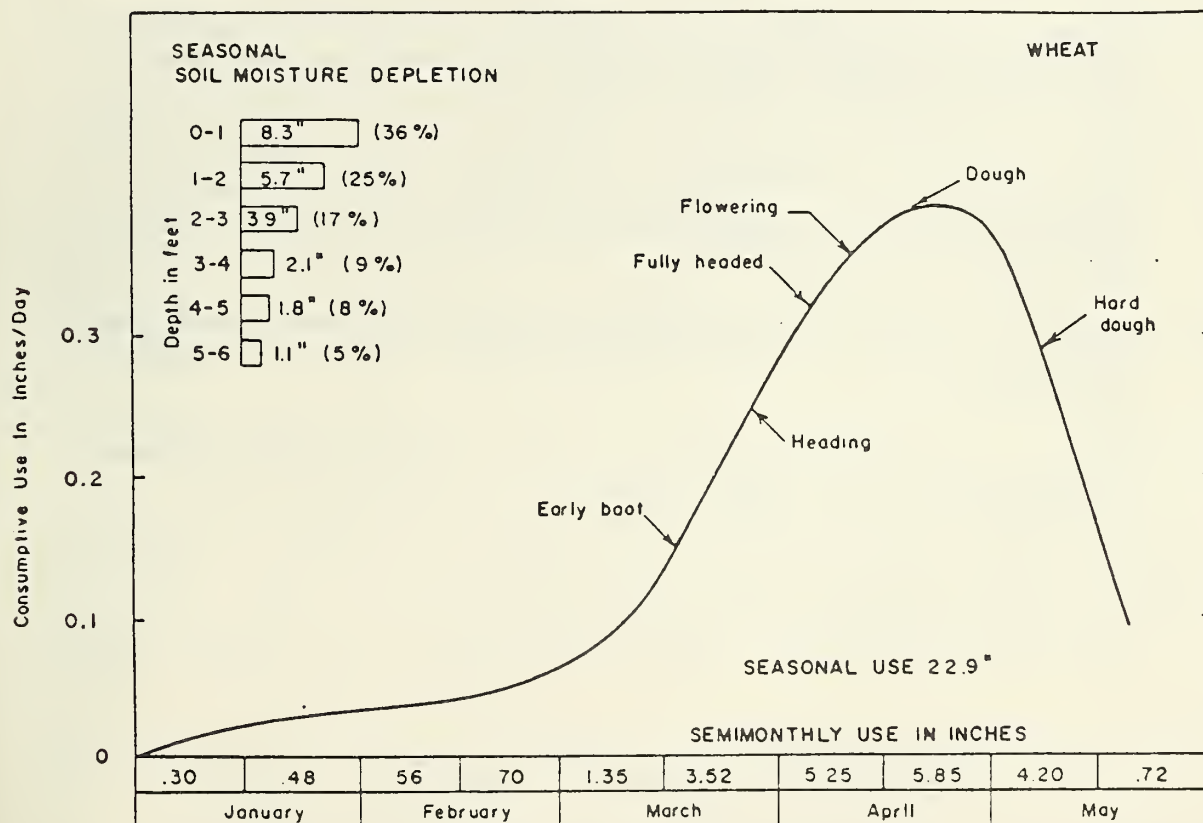
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Irrigation at critical stages of plant growth

A knowledge of the consumptive use pattern of crops is important in scheduling irrigations. In the example shown here, the peak use of water by wheat occurs during April and the amount of water used during April is about twice the amounts used during March and May. Both the total amount of water used and the time of the peak water need are different for various climatic regions in the U.S. but the general shape of the curve would be similar for all areas. Consumptive use curves are available for most crop and climatic regions in the U.S.

Some crops have a critical growth stage when the plant cannot endure water stress without large yield reductions. For corn this period is at tasseling and silking while for wheat the critical stage is at heading and filling of the kernel. For soybeans the period when the pods are filling is more sensitive to moisture stress than other stages.

Sorghum is considered a drought tolerant crop but moisture stress at heading or milk stage of grain reduces yields more than at other times. Stone fruits are sensitive to moisture stress during the period when



Mean Consumptive Use for Wheat at Mesa, Arizona. 1959-1960.

the fruit is rapidly expanding. When irrigation water supplies are limited, applications should be scheduled to apply moisture stress at growth stages which are least sensitive to water stress.

Other crops such as cotton, sugarbeets, forages and citrus fruits do not have a growth stage that is particularly sensitive to moisture stress. For these crops, limited irrigation supplies should be scheduled to provide a uniform fraction of consumptive use during the entire growing season. For example, if water supplies are 10% below optimum the consumptive use curve should be followed and 90% of the water needed should be applied during each irrigation.

If water supplies are very low fruit trees can be kept alive by applying enough water early in the season for leaf development and then reducing water applications to cause fruit drop and early dormancy.

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Range Management and Conservation of Water Supplies for Livestock

Range and dry pasture forage production depends entirely on natural moisture. Overgrazing during a drought does more damage to perennial plants than during a season of normal moisture. It reduces plant vigor, stops root and leaf growth, reduces ground cover, and invites accelerated erosion. Once erosion begins, it tends to get worse each year, further reducing plant vigor and forage production. This process is difficult to reverse.

Rather than risk permanent damage to grazing resources livestock numbers should be reduced to balance with forage supply by culling herds more than normal and selling calves and lambs early. Supplemental forage could be produced by growing small grains or sorghums for hay or pasture (these need less water than conventional forage crops). Planting perennial pasture, hay, or range seedings should be deferred until a year with more favorable water outlook.

Cooperative research by ARS and the Oregon Agricultural Experiment Station at Burns, Oregon suggests methods for minimizing water use by beef cattle and for improving range utilization.

Allowing yearling cattle to drink only every 48 hours during summer grazing on range reduced total water consumption by 25 to 35 percent without permanent effects on weight gains. Forcing them to trail 1 to 2 miles per water effected similar reductions in total water consumption even though they went to water each day.

Water consumption of cows was similarly reduced by these treatments without permanent adverse effects on their weights. Actually, they gained more weight probably as a result of reduced milk production. Gains of calves were adversely affected, in some cases severely, especially after 3 to 3½ months of age.

Watering yearling heifers every 72 hours on range resulted in weight losses but all survived.

These results suggest that when water is being hauled to range cattle to permit utilization of ranges with no natural water supplies, considerable saving in water hauling costs may be obtained with a 48 hour watering interval. Performance would not be permanently affected if grazing animals were non-lactating types. This should not be done with lactating cows and calves.

ARS research and reviews of research by others have summarized water requirements for several ages and classes of livestock.

As a generalization, requirements are quite variable. They are greatly influenced by environmental temperature, and by kinds and amounts of feed consumed as well as by age, weight, and species of animal.

Thus, when water supplies are limited, calculations based on probable requirements of particular kinds of livestock in given environments should be used to determine supplemental supplies required.

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